Geographic Information Systems
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Lecture – 26
Introduction to GPS

Hello, Namaste, welcome back to the course on geographic information system, today we would be speaking on global positioning system, I have given you enough introduction about global positioning system, I have spoke about how it can aid in data collection and maybe validation in many terms. So, global positioning system by default is a standalone system which make may be useful for many purposes.

I will give you first, this is a set of entire module is based on global positioning system, I would look at how, what do you mean by a global positioning system, if you do you have any of the systems that is parallel to global positioning system and if there are parallel system, what are its advantages, what are its disadvantages and how we are moving ahead with various other systems which can actually help us in better data collection and also navigation. The very important aspect is navigation, so let us look at all of these aspects in this particular module.

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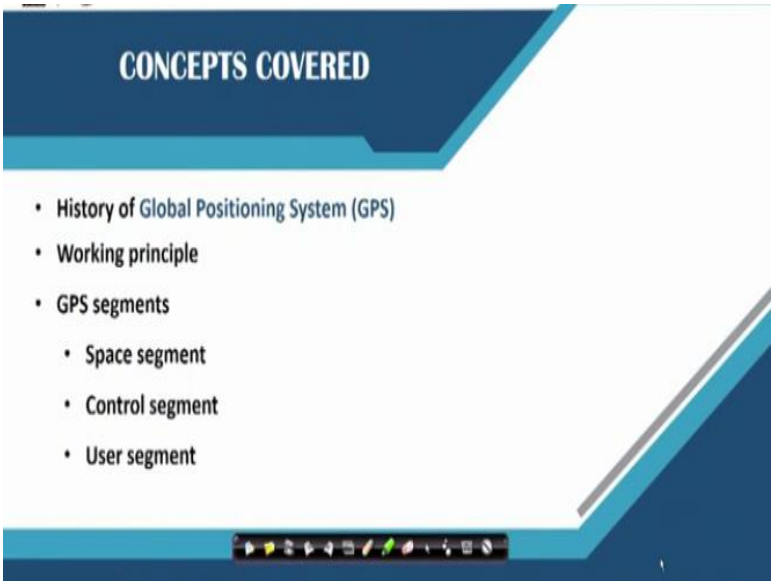

In today's class, I would look at the history of global positioning system, it is very good to understand the history of what global positioning system is; then let us look at working principle

of global positioning system. So, once we have understood how the global positioning system works then, we would look at different segments in a GPS that is a space segment, a control segment and a user segment.

How each of these segments are designed, how these are operated and what are its different I mean, when you are looking at an entire system, what is its contribution to overall system, let us look at all of these one by one.

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Now, when I say global positioning system, so global posting system if I have to define, it is worldwide radio navigation system, this is formed from the constellation of 24 satellites now, it is total number of satellites is about 27 and a ground station, so you need to have satellites, you need to have ground stations and you need to have a control station where in and also the receivers.

So, the first thing that we have to understand is we have 24 satellites which are dedicated to the GPS signals, every part of the earth should at least have 4 satellites visible, so that you have a good GPS signal or your whatever measurement you are trying to do is perfect. So, GPS was first launched by Department of Defense in 1974, it was fully operational by 1995. So, when I say, fully operation entire 24 satellites were operational by 1995 then they introduce a term called as selective availability.

For example, let us say if I have a friends group okay, if I have to let us say, just give selectively certain things to my friends, so I would only select few of my friends who will have the best system, whereas other selects to a select friends may not have the entire measurements to be very exact that is what US department said. So, it was giving certain uses only the best available signal whereas, other users used to have or he did not have an access to the best available signal on board in the GPS navigation system.

Then in 2005, GPS modernisation effort was launched and it is as of now, it is quite modernise in terms of whether it is navigation or in terms of the measurements that it provides.

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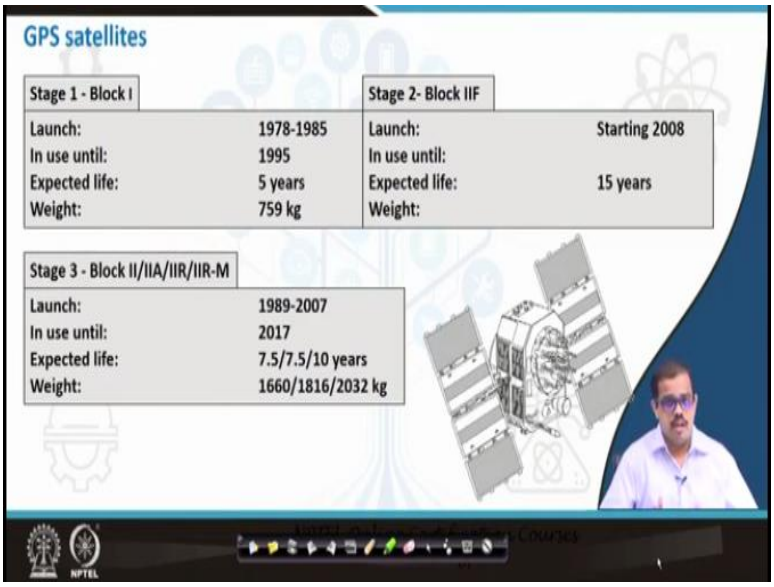

So, when we look at different stages, it was basically, many stages but if we can put into blocks and we can put it in stage 1, stage 2 and stage 3 block. Stage 1 block was from 1978 to 1995, it was; it is expected life was about 5 years but it was used until 1995, which means it is an even beyond its expected life. Then block 2 constellation of satellites was launched starting 2008, so it is expected life as about 15 years and is yet working.

And has been extremely useful in terms of both navigation and distance measurements now, stage 3 was with block 2, 2A, 2R and 2R to M, so all of these blocks were large but somewhere between 1989 and 2007, okay but this was used until 2017, this had an expected life-cycle

somewhere around 7 years to 10 years, okay but the weight were also about good weight but this was supposed to be working till 2007. But it continued till 2017 which showed that these had a very good capability of even looking beyond it expected like, okay.

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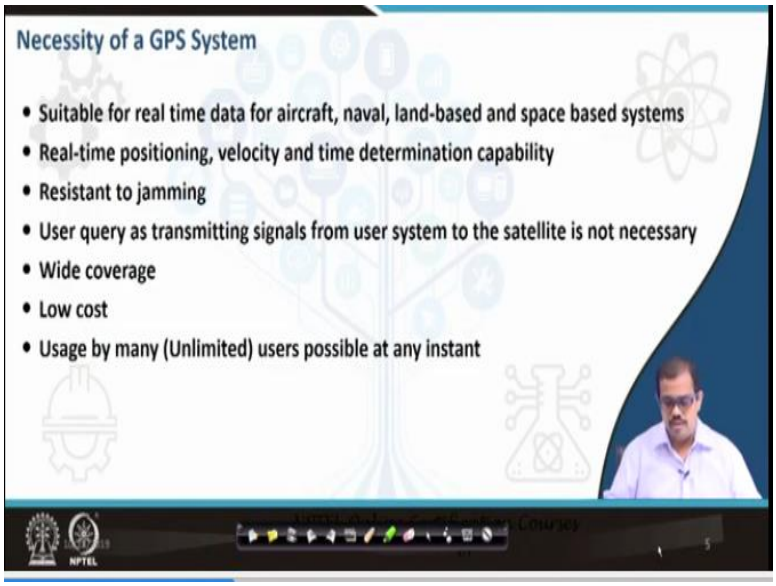

Once we have all the systems were launched, the first question anyone asks me if you want to have a GPS, first thing; why do you need a GPS okay. If you really want to understand why do you need a GPS, let us go back to our daily routine, so most of you, most of us use a mobile phone and basically, it is an android phone at least 90% of people who use mobile phones, we are using android phone or iOS phone.

So, now with this and most of us navigate in a city specifically or in the outskirts of the city through your Google maps, so what is this how does the technology works? Your mobile system, most of your mobile system has an AGPS which means that it is an assisted GPS, so when I say assisted GPS, it means to say that this particular GPS chip that is inside your mobile needs and assists think capability that is from either from your data, Wi-Fi etc., which actually locates each and every towers at a particular location, adjust the locations as per the availability.

So, most of these system, so when you use such GPS, you are actually locating yourself on the earth's surface or understanding what location is this or finding out the distance between you and other location or trying to find out the distance between 2 points, right which means that in

everyday life, every human being is now subjected to such kinds of unlessens, so when if that is the case, then that becomes a necessity, right.

If you want to, not everyone will know every point on the Earth's surface or may not be even entire city, if you are from a particular city like Kolkata, not everyone will know every point to drive to every location, so you need certain play, I mean ways to navigate and as far as today's city is as say India, when you look at Indian cities are quite very complex lipid. So, if you have to really navigate into most of the streets, the most of them are unknown streets, whether, whichever city you are.

So, you have to navigate by using certain navigation system and GPS provides a good backbone in such navigations. So, when we look at GPS system it is actually suitable for a real time data for air craft, naval, land-based and space-based systems. Most importantly, that as I explained already, real time positioning, so real time positioning is extremely important, velocity and time determination.

I will come back to how the real time data for air craft is used, it is something call as a WAAS system; WAAS, so we will come back to that in further slides but as of now just understand; just I want you guys to understand that this is suitable for data for aircraft, then very importantly, is that most of your mobile phones can be jammed, right, so these GPS systems are resistant to jamming, you cannot jam that particular channel of the way the GPS acquires its signal.

So, user query as transmitting signals from the user system to satellite is absolutely not necessary, it means to say that you need not send a query from your mobile phone to the satellite okay, what basically happens is that whatever the query you are trying to do is sorted out by the local server of that particular app. For example, if you are using a Google app, it means to say that it is utilising the database that is stored in the local server and tying it spatially, so that you locate a particular point.

So, once you have located that particular point, then using the GPS, it will locate where you are okay, so GPS does not need any user inputs from the earth's surface whereas, user needs input

from the GPS in order to locate himself or herself, so that is why that is what is one of the advantages, so you do not need a two-way communication, you have only one-way communication.

And most importantly, very wide coverage okay, entire surface is covered by the satellite, that is what I said you have 24 satellites which are revolving around the earth surface and that provides the entire, I may covers the entire earth's surface and whatever necessary part it is, then most importantly whatever today's analysis is based on it is low cost. So, when you look at low cost satellites provide you all the I mean, GPS provides you all the details at absolutely no cost, right.

So, usage by many users possible at any instant that is the best point, so when I say let us say, at any point it is estimated that 18.1 million at every second use the GPS signal for the navigation across the globe. So, when you look at 18.1 million people using each and this account is actually growing by another 18,000 users every second or every day. So, when we look at this particular aspect, so you can see the huge user pool, who is capable of actually augmenting the system and using it.

So, if we are able to reach to a larger pool it means, that particular system is working extremely well, so that is why it is not very limited to particular number of users say, if it was limited then probably we would not have enjoyed such navigation facilities in many of our city or across the country, so that is very big advantage when comes to a GPS system, it is unlimited to any number of users who use that.

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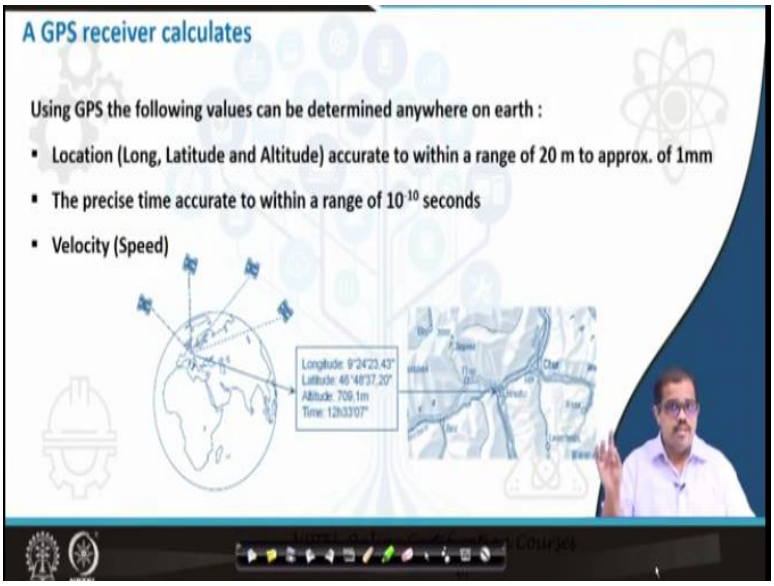

So, when we all look at a GPS; so if many of you would have seen a GPS, normal GPS system by itself or many of you would have use GPS in your mobile phones, so these GPS has many values to determined, basically 4 values to determine anywhere on the earth. The first thing it looks at is latitude, longitude and the next thing is altitude. So, normally most of this based on the what positioning service it is approximate to 20 meter; 20 meter approximate of 1mm, okay.

So, this is the position of it, I will come back to what kind of standards or precise standards that they use, so in terms of that it is almost closer to 10 meter to 20 meter in terms of its presentation. The precise time accurate to would be a range of 10 power minus 10 second, so that the fourth; the third quantity that it would measure is time, so it will be 10 to the power of minus 10 seconds.

So, it is latitude, longitude is 1 quantity, altitude is the second quantity, third quantity is time and the fourth quantity is velocity, speed, so that becomes a very important aspect when you are navigating, so that is also captured by a GPS. So, you have 4 quantities, which is actually captured by the GPS that is your point data that is where your latitude, longitude and it calculates your time, altitude and finally the velocity, okay.

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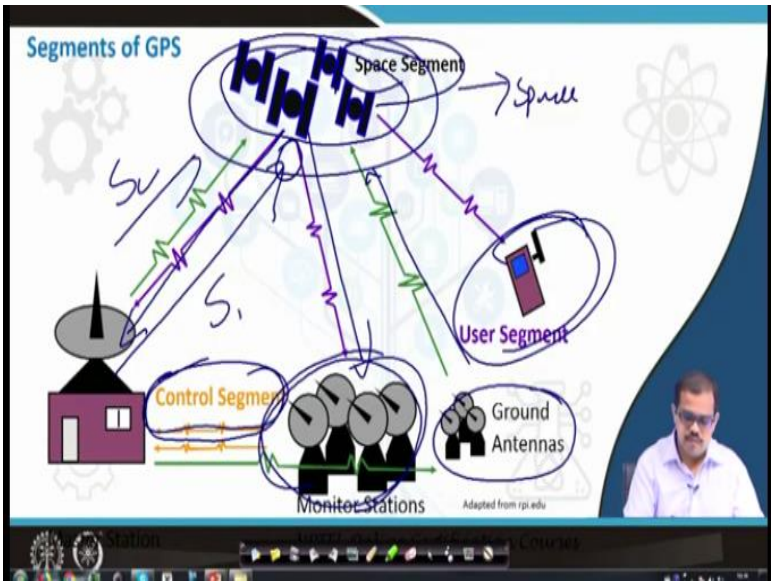

So, let us look at how actually a GPS works, now it is as; it is not as simple as that you just have a GPS system with you and you run around and that signal calculates but how it actually comes to your particular mobile phone, so that we have to look at in a greater detail. So, when we are looking at this point, the first thing here is the set of satellite, okay the constellation of satellites. I said it is 24 satellites, so this segment where it is the satellites are revolving is nothing but called as a space segment okay.

So, this satellites what they do is; they captured the earth's surface, the signals across the earth's surface, the way it is moving. Let us say, now, then it communicates it with the control systems or the control segments, once you have the control segment; control segment is actually meant to be on the earth's surface in order to either correct your errors that are present in that particular signal that GPS that the space segment is actually sending him.

Or it is actually looking at various other corrections, issues that may have happened and controlling of this entire space segment. So, now once the correction is made here, it sends back the signals back to the space segment now, this space segment once you gets corrected, let us say, the signal 1 that is corrected is S and the sent back signal is SC. So, now this SC signal is then transmitted to the monitoring stations, that is that here, okay.

Many a times it is ground antennas also provide some input in terms of corrections for the space segment, I will let you know how it does but as of now, if you see it is you have a space segment which sends a signal to the control segment which is on the ground or it is called as a ground segment and the corrected signals are sent back to your satellites. Now, once the corrected signal is sent back to your satellites, any number of users can use it on and it is then distributed into the earth surface, where there is certain distortion due to ionosphere etc.

Based on this, there is a certain laws and the signal that is not lost reaches the earth surface which can be used for monitoring stations and in the user segment, so these; this is how the entire segments of the GPS works, let us understand each and every segments of a GPS in a better way, okay.

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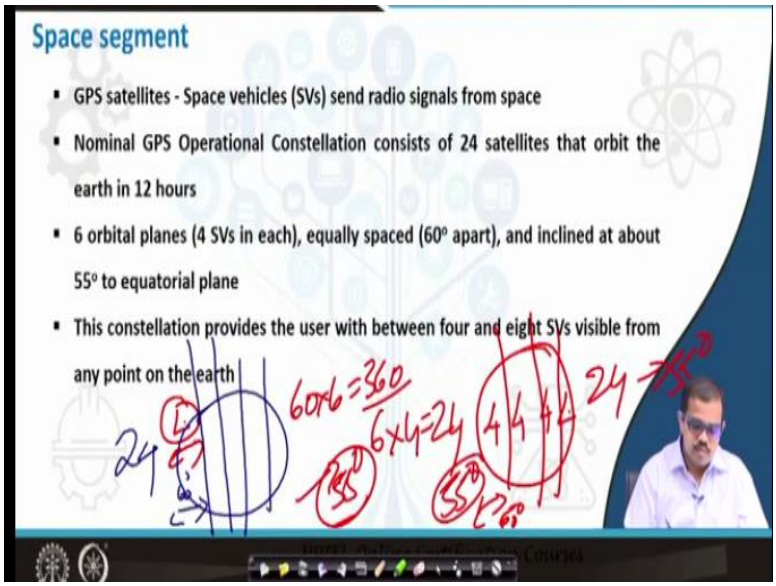

So, yeah, so when we look on this space segment, GPS satellites has space vehicles and the radio signals from the space, so as I said this space segment is basically, a collection of satellites or the space vehicles. Now, these send the radio signals from the space, each of the nominal GPS operational constellation consist of 24 satellite, just I have told you before so, it consist of 24 satellites and that orbit the Earth in 12 hours.

Now, when you look at this, when you look at the entire earth surface here, earth surface is divided into 6 to different orbital planes, each plane having 4 satellite vehicles, so 6 into 4 is 24

satellite vehicles all across the globe and each of these satellites are inclined at 55 degrees, so all of this 24 satellites are inclined at 55 degrees and each of this orbital plane is 60 degrees. So, let me go back and explained it in much different way.

First you have a 64 satellites; you have 64 satellites so, when you look at when I, let us say we have 24 satellites now, when you look at this as a Earth's surface, this is divided into 6 planes okay, each plane at 60 degree each okay, now when I say 60 degree, so 60 into 6 planes is the 60 degree, which is covering the entire Earth's surface, each 60 degree will have 4 satellites, 4 into 6 is 24 satellites across the globe.

And each of these 4 is inclined at 55 degrees to the Earth's surface; to the equatorial plane okay, so this is about how this space segment looks, this constellation will actually provide you at least a 4 signals anywhere across the earth's surface and is limited to about 8 satellite where vehicles that is visible from any point on the Earth okay. So, either at is 24 or at is 8 signals that is visible across the Earth's surface, okay.

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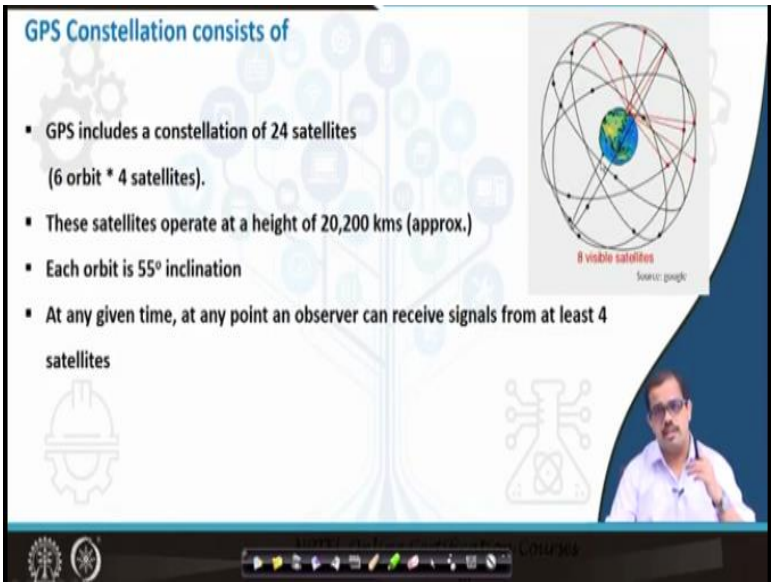

So, now when we look at the entire GPS constellation as I said let me explain it in detail, so it is for constellation of 24 satellites, 6 orbits, 4 satellites every orbit 60 degrees okay, so these are satellites operate at about 20,200 km approximately so, keep this in mind. So, you have polar

orbiting satellites, you have geo station satellite and your most of your GPS satellites are about 20,000 to 100 km approximately.

So, when you look at are set of information, you will be able to understand where the cycle of its kind of satellites and where it is inclined to, then each orbit is has a 55 degree inclination at any given point of time, any point on the observes receive signals from 4 different satellites, so this is what I explain in my previous slide, so just to show you this particular image here, this is actually an image that I searched out from Google which actually explains how the satellites move across the earth surface.

And when you see most of this, this is the earth that is actually rotating and you can see these are red signals that are shown which is actually, representing the satellite signals on every point on the earth's surface. So, if you see below this is actually, showing how many satellite visible; satellites are visible at any point on the earth surface as it moves, you have at least 4 to 8 signals may, sometimes it is 6 to 8 signals all the time, okay, 4 as a minimum signals that you need.

I will explain why do you need 4 but you need at least 4, but maximum that you can get is about 8 satellites at any point of time, okay.

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So, this is a nominal constellation of the satellites, this when you look at this, you have as I explained, you have 6 orbital planes and every it is at 55 degree inclination, every satellite is at 55 degree inclination from the equator.

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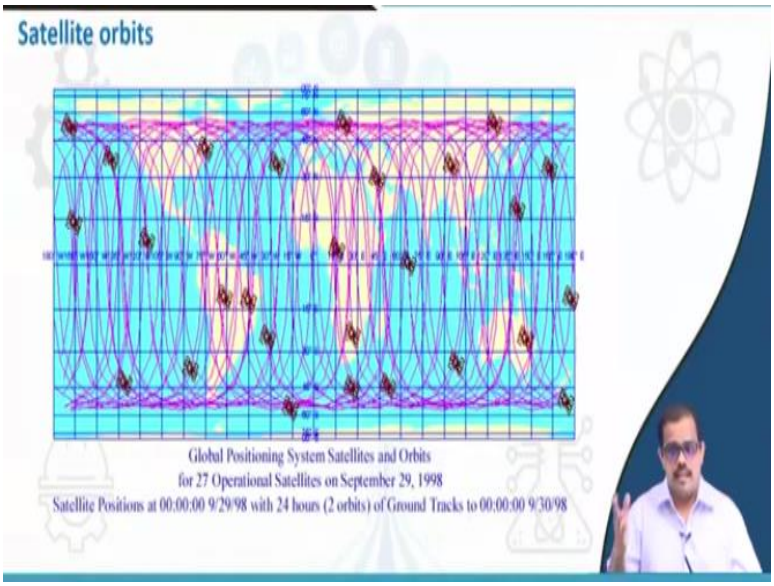

So, this is how the satellite orbits and if you see each of this, when you look at this entire system that any point on earth surface, you can see at least 4 satellites will be there at that particular point of time, this was a image that was taken on 27th September, sorry 29th September where 27 satellites were operational, this was in 1998. So, if you could see every point on the earth surface is covered.

So, if you are any point on the; in India at any place you can easily receive about 4 signals yes, there are places where the satellite signals are really weak especially in web, they have we have thick canopy vegetation etc., so we have different methods of again, getting a better signals. So, you can either use a certain ground control stations or use a DGPS for corrections and use better signals in from the DGPS or use some, many other system that is available now.

We will discuss all of these in my next slides but at any point on the surface at least 4 signals should be available, okay.

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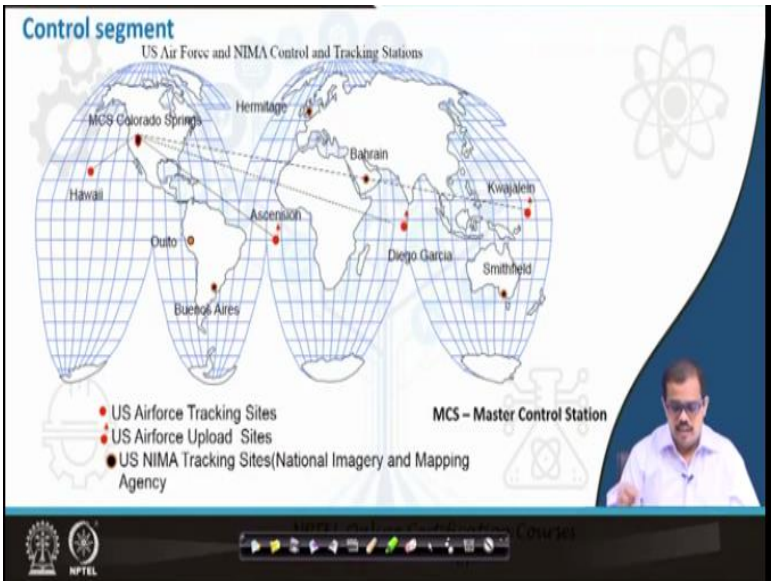

Then, the next segment is a control segment now, when I say control segments, US Department of Defence has its own way of maintaining the entire control segment, it has main, very main control segment, it is also called as a master control segment which is located at Colorado which is in US, so if you look at this is the main control segments and it has different sites across the globe, which is actually an tracking site.

So, this tracks the real movement of the satellites at any point of the time, then you have the US Air force upload sites, which is mentioned it with an arrow here, if you can see here, so these are the sites where US Air force actually look at particular position of the satellite, it is also mentioned that it is a quite precise in terms of Air force applications and when you look at US NIMA tracking sites that is National imagery and mapping agency which is for most probably, for your public interface.

So, you have sites that are located here in Bahrain, in Buenos and in Smithfield, so all of these regions are for your imagery and mapping agency and most importantly, for basically for civilian purposes where the civilian signals are actually corrected and sent back, okay.

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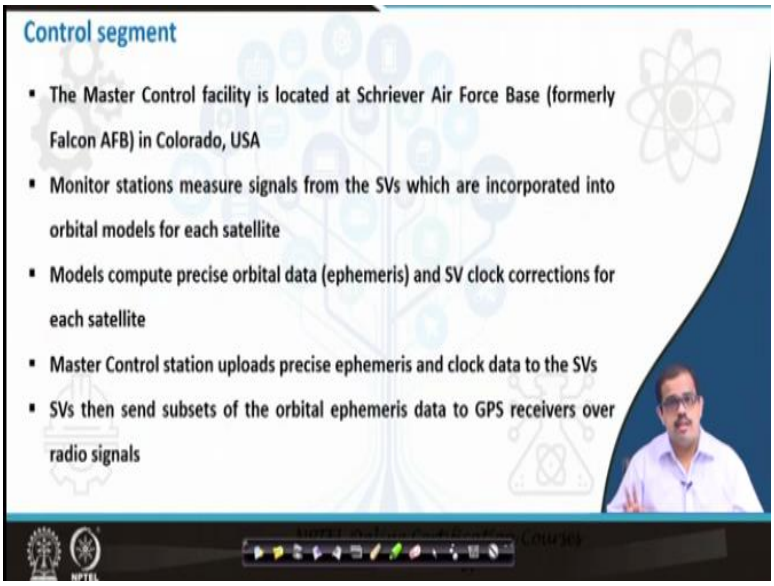

So, as I said the master control facility is located at all in Colorado, USA so, this facility is the master station which actually controls the entire operations of the GPS satellites, I would say I would repeat again, GPS is an entire segment is maintained by united states of America, it maintains the entire fleet of satellites (()) (24:37) satellites are there today in the space segment.

And it is responsible for its operations all throughout, then we have monitor station measures signals from the SVs which are incorporated into orbital models for each satellites okay, so this is a very important point where the signals are sent into r satellite vehicles, so that the orbital models for each satellites are computed, then the models compute the precise orbital data, this is extremely important in terms of your signals.

So, once the signal comes from the satellite on the space segment, the models compute the very precise orbital data and once you are precisely calculated orbital data also calculates what is this satellite vehicle correction, if your; in the clock of the satellite should match the clock at the earth surface at that particular point. So, when you are correcting its clock, it is also correcting various other variables that have linked to the movement of the GPS and moment of the earth surface.

So, with this correction, the signals are sent back to the satellites, so the master control station uploads the precise ephemeris and clock data to the satellite vehicles. The satellite vehicles then

send subsets of the orbital ephemeris data to GPS receivers over radio signals, so if you can understand this first, the signals are sent, the signal; the raw signals are sent to the control stations.

But when again, once the corrected signal is sent back to the satellite, the signals that come into the earth surface is in the form of a radio signal, okay, so that is what we have to understand.

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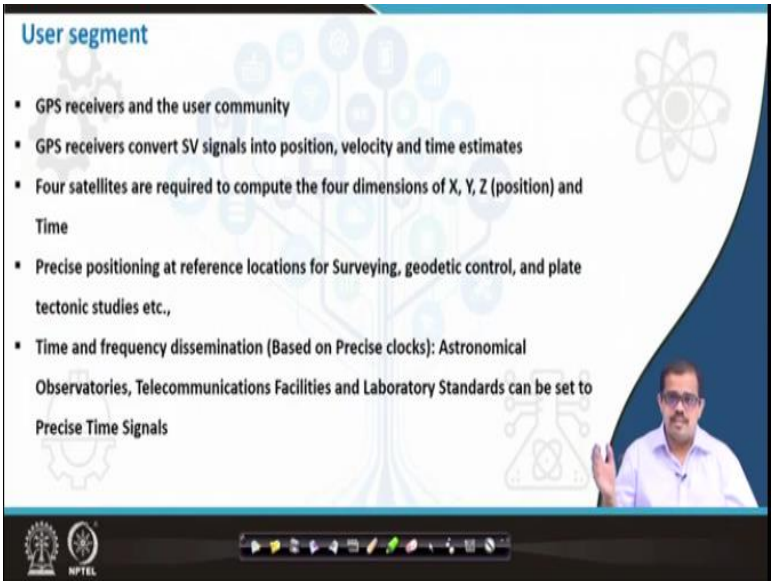

Then the third segment that we would see, if the space is first, the control is next now, you are sent back the corrected signal to the space station again now, the one that receives that corrected signals is the user or the user segment. So, GPS receivers and the user community use this are the part of this particular segment, GPS receivers convert the satellite vehicle signals into position, velocity and land estimates.

Four satellites are required to compute the 4 dimensions of X, Y, Z and time so, when you are looking at X, Y, Z, how do you compute will look at it but as of now, it is required for to compute 4 dimensions of X, Y, Z and time, precise positioning at reference location for it may be use for surveying, it may be use for geodetic control systems, plate tectonics studies etc., many studies.

Today, there is no study that can mention that there is no application of the GPS, so you can have many of the studies where in way, it is involving in the earth surface, involve in the process control, all phenomena, you have; you need GPS system that are, any of those systems which is similar to the GPS for your analysis. Time and frequency dissemination that is based on the precise clocks, astronomical observations, telecommunication facilities, laboratory standards, all of these can be done using a precise time signals.

So that is why you need a control segment to control and correct the errors and once it is corrected, user segment can use it for various applications on the ground.

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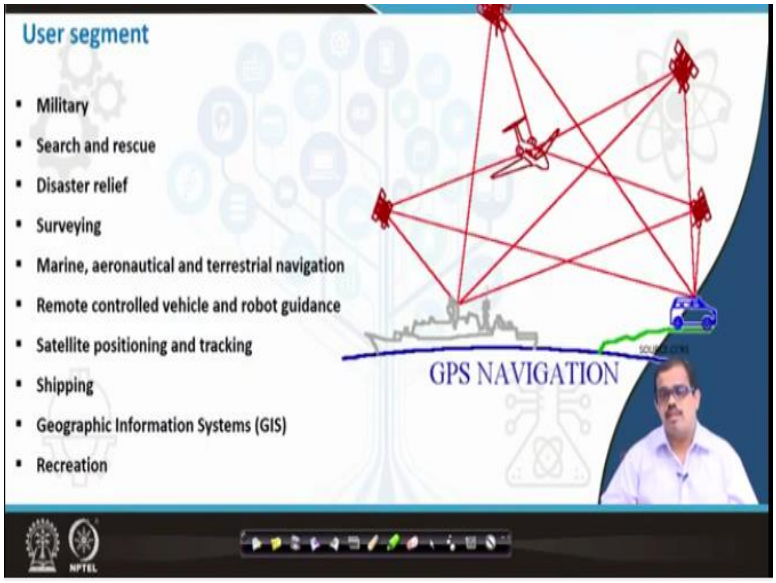

So, this about the user segment and when you look at it, the first thing that you get in the GPS is GPS navigation, this is one of those images that I got have carried it from the Canadian space centre which is actually giving you an abstract of how a satellite is actually, interacting with various quantities; various entities on the ground, it may be ship, it may be your air craft, it maybe your cars where you navigated to various locations, it is just use a one applications.

Similarly, when you look at the entire user segment whether it is a military segment, whether it is a search and rescue, so operations that can happen and disaster relief, this is very major thing that the application of GPS has happened in recent years, disaster has been a very big segment, very

big operative region, where GPS is used, then surveying; surveying has been when the manual surveying is extremely tedious but when you are using a GPS system, it becomes much easier.

And marine system, aeronautical, terrestrial navigation, all of these are certain applications which can be used, then you have remote controlled vehicles and robot guidance, this has been increased over a period of time and you can see now the huge number of remote controlled vehicles and most of your very important vehicles in terms of financial importance are any other or maybe you political influenced vehicles, always have been under the robot guidance.

And also, under your remotely sensed vehicles, so this is again through a GPS, so they track all of these vehicles through a GPS system, then you have satellite positioning and tracking that is also very important, then shipping. So, the major user of this is again shipping and the aircraft, then GIS that is what we are trying to understand, then the last part is recreation so, there are lot of applications for recreation, which is coming up in the very recent years.

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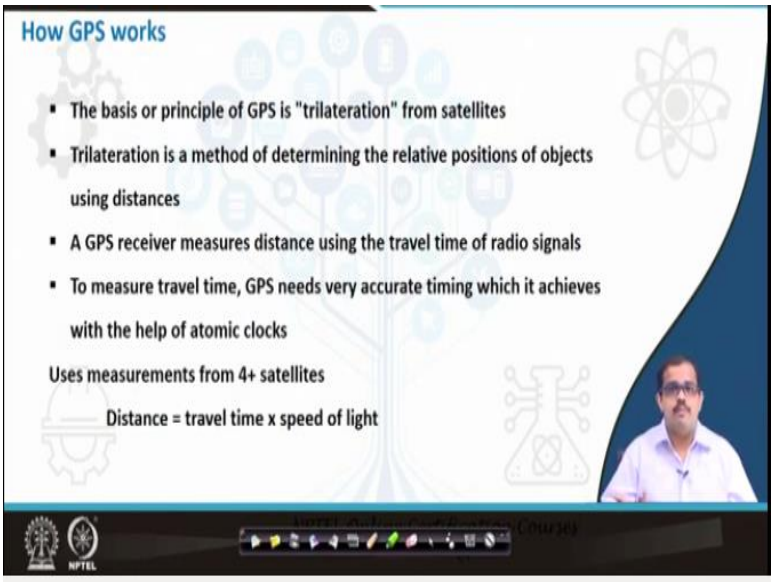

So, with this we have understood how the GPS system is now, let us understand how GPS works. So, I did inform you that GPS needs at least 4 signals but it works on the principle of trilateration from a satellites okay. When you are looking at trilateration, it is about the method of determining the relative position of the objects using distances, so distance is a measurement point here or the distance is the reference point.

A GPS receiver measures distances using that travel time of the radio signals, so when you look at; I did our inform you that once the corrected signals is sent back from the control stations to the GPS system, GPS sends the only the radio signals to the earth surface of the user segment, these radio signals it measure; with this radio signals, the major measurement that is done is distances using the travel time method. How do you measure it?

Distance is nothing but travel time into the speed of light, travel time of these radio signals into the speed of light that is how you measure the distance. Then to measure travel time, GPS needs a very accuracy accurate timing which it achieves with the help of atomic clocks, these atomic clocks are on-board the satellite vehicles that is what is the clock correction that you do using your control stations.

So, if that is correct then it means to say that your GPS would give you very accurate results okay.

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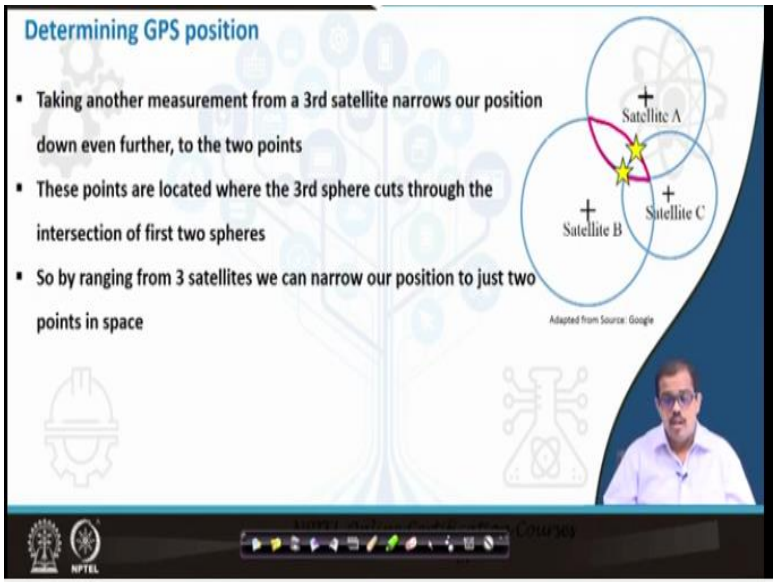

So, when you are looking at determining the position of a GPS, for example let us say that when there is a single GPS vehicle, my position can be somewhere about 17,700 kilometres from the GPS satellite. So, it can be anywhere on the surface that it is looking at to, in the 60 plane, it will

be looking at some position, it cannot relatively give me what position that is now, if I have the second satellite let us say we have a satellite B, okay.

Now, with both of these satellite, it narrows down to the position here okay, so it says in between both of this position somewhere the user is located, okay which means to say that it is actually narrowing down to that only that particular location. Now, let us say we have the third satellite okay, the third satellite narrows our position further into any of these 2 points, where it is actually intersecting the first 2 satellites.

So, which means to say that by the third satellite signal, we come down to thing that where the sphere cuts the 2 points that is where the user is actually located either 0.8 or 0.3. Now, we know that either he is here or he is here or she is here or she is here.

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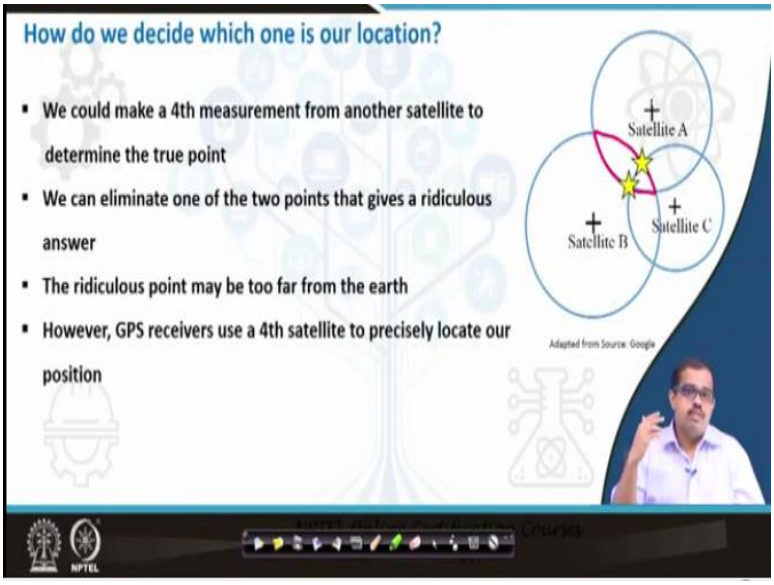

So, with these 2 points we try to find out what is a 4th point because when the fourth measurement is done, let us to measure a true point. So, how can we do that? We look at which is the point or the satellite looks at which is a point that is extremely ridiculous, okay which may be in the range with not be very; in the range or it is too far from the earth surface. So, with this it will precisely locate that this is a particular point which is, where the user is actually located at this altitude.

So, which means to say you need 4 satellites, each of these satellite signals giving you 4 different measurements okay, X, Y, Z and your velocity okay, so Z is the time.

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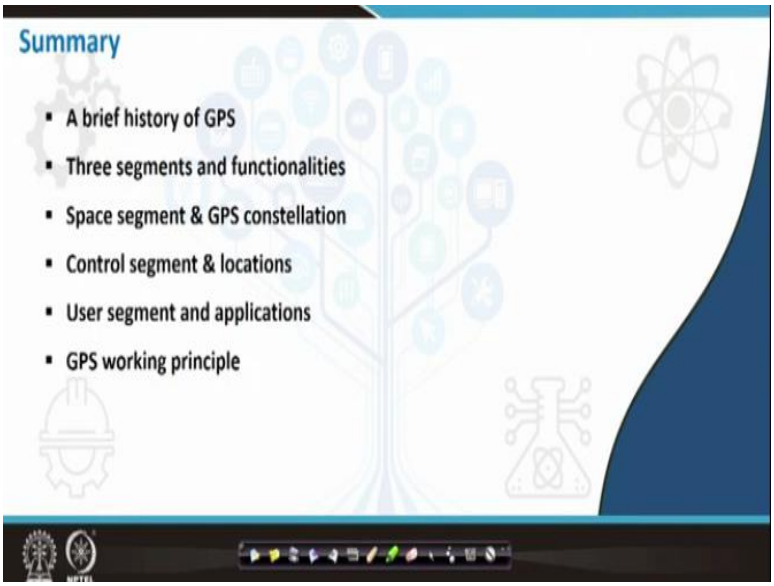

So, with this we will end this class, so now we have understood in this particular class, what are the different segments in a GPS, we started with the history of GPS, how the GPS started, we have looked at what are the different segments in a GPS, we did discuss about what is the user segment, your control segment and your space segment. So, space segment is constellation of satellites and the radio and the signals that it can send.

Then, the control segment is where the signals are received and is corrected for any errors, you just sent back, the user segment is finally receives the radio signal and that is where the applications happen, so we looked at that we looked at different how the space segment is located, there are about 24 satellite vehicles at every 60 degree, so you have 6 working planes. So, with this you have the entire constellation and each satellite is at inclined at 55 degrees.

So, this is what we mean by the space segment, then we looked at control segments and its location, the master control segment is located in Colorado, USA and different control units that are across the globe, we looked at even the national mapping agencies, different points on the earth surface which is majorly for a civilian purposes and once you have looked at it, we finally looked at how GPS locates a point on the earth surface.

So, with first just one satellite signal it can give you in that orbital plane with any; with very high displacement value that you are located somewhere here, with 2 satellite signal it narrows down to a location where both of them; both of the spheres are intersect and with the third one, it actually narrows down into a point where all the 3 spheres intersect and 2 points that actually are the intersection point.

With those 2 points now, it will look at which is the best point and which is the point that may not be that particular locations, so with the best point, it gives you where you are okay, so this is how you are located on the earth surface through a GPS system. So, in the next class we would look at more on the GPS system and also look at how it works and what are the different principles behind it, how the applications are there and in next 2, 3 classes, coming classes in this week. Thank you very much see you then.